Endovascular repair of extent I thoracoabdominal aneurysms with landing zone extension into the aortic arch and mesenteric portion of the abdominal aorta

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Thoracic endovascular aortic repair (TEVAR) has emerged as an alternative for patients at prohibitive risk for open thoracic or thoracoabdominal surgery, decreasing perioperative morbidity and mortality. Aneurysms that involve both the left subclavian artery (LSA) proximally and the celiac artery (CA) distally present a unique challenge to the use of TEVAR. We report a series of six high-risk patients presenting with extent I thoracoabdominal aortic aneurysms who were successfully treated with TEVAR including coverage of the LSA and the CA. (J Vasc Surg 2010;52:460-3.)

Endovascular repair of isolated descending thoracic aortic aneurysms has emerged as an alternative to open repair in selected patients, decreasing perioperative morbidity and mortality when compared to open thoracic or thoracoabdominal approaches. Anatomically complex aneurysms, including those that involve the aortic arch and mesenteric vessels or those that have short or diseased landing zones, have complicated and limited the widespread application of endovascular therapy to thoracoabdominal aortic aneurysms (TAAA). Several treatment modalities have emerged in the treatment of complex aneurysms, including hybrid procedures, branched or fenestrated endografting, and endograft placement with coverage of aortic branches with or without revascularization. To date, there are no dedicated case series of thoracic endovascular aortic repair (TEVAR) to treat extent I TAAA. We report a series of six high-risk patients presenting with extent I TAAA successfully treated with TEVAR including coverage of the left subclavian artery (LSA) and celiac artery (CA).

CASE REPORTS

Between August 2005 and April 2009, 305 patients underwent TEVAR and were entered prospectively into a surgical database. Six patients (2.0%; 2 men, 4 women) with extent I TAAAs were identified retrospectively. These patients required proximal landing zone extension into zone 2 of the aortic arch and distal landing zone extension into the mesenteric portion of the abdominal aorta, with coverage of the CA to achieve adequate aneurysmal exclusion (Fig 1). Patients were a mean age of 76.3 years (range, 70-83 years), and the average maximum aneurysmal diameter was 6.8 cm.

Except when contraindicated in one patient by renal failure, all patients underwent preoperative computed tomographic angiography (CTA) to evaluate collateral circulation between the CA and superior mesenteric artery (SMA). Three of these five had SMA to CA collateralization through the gastroduodenal artery, one had a replaced right hepatic artery from a patent SMA, and one had a chronically occluded CA. Preoperative CTA showed all patients had patent superior and inferior mesenteric arteries and internal iliac arteries. In all cases, hepatic perfusion was verified with a predeployment visceral aortogram and a postdeployment completion angiography.

The six patients underwent left carotid-to-LSA bypass 3 to 5 days before aortic repair. At the time of TEVAR, left brachial sheath access was established for coil embolization of the LSA stump proximal to the bypass and to the left vertebral artery to maintain left upper extremity and posterior cerebral perfusion.[1] The proximal landing zone in all six patients extended to zone 2 of the aortic arch to include complete coverage of the LSA origin. All procedures were completed under general endotracheal anesthesia, and cerebrospinal fluid drains were placed in all patients. Gore TAG (W. L. Gore and Associates, Flagstaff, Ariz) or Zenith TX2 (Cook Endovascular, Bloomington, Ind) endografts were used.

Follow-up consisted of CTA and physical examination at 1, 6, and 12 months postoperatively and then serially every 12 months thereafter. Imaging studies were evaluated for the presence of endoleak, device migration, and aneurysm sac size.

Proximal sealing without evident type I proximal endoleak was accomplished in five of the six patients (Fig 2). The average proximal neck length was 20.0 mm. Two patients required partial CA coverage by the distal thoracic endograft to ensure adequate

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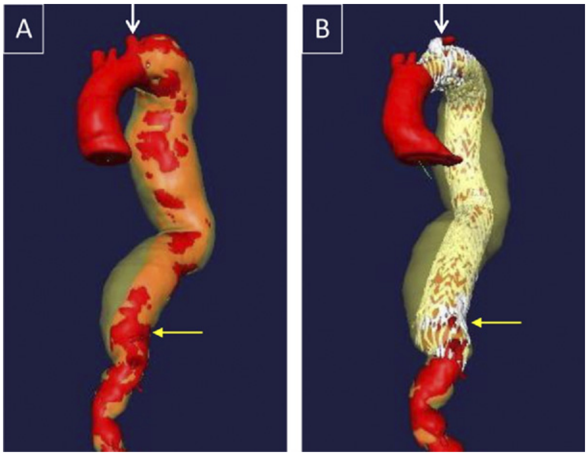

Fig 1. Three-dimensional reconstructions of a computed tomography angiogram using M2S software (West Lebanon, NH) show an extent I thoracoabdominal aortic aneurysm **(A)** preoperatively and **(B)** after thoracic endovascular aneurysm repair. Note the landing zone extension to include coverage of the left subclavian artery *(white arrow)* proximally and the celiac artery *(yellow arrow)* distally.

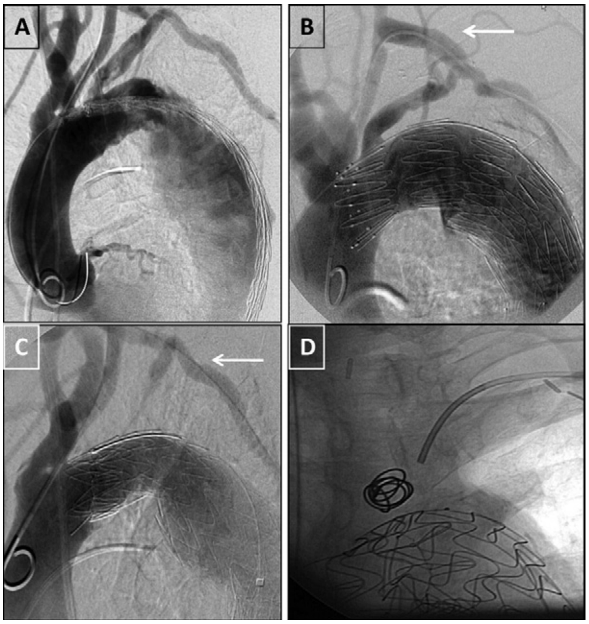

Fig 2. **A,** A predeployment aortogram shows the proximal extent of the thoracoabdominal aortic aneurysm. **B,** The postdeployment aortogram shows landing zone extension into the aortic arch with a patent left subclavian artery (LSA) bypass *(arrow)*. **C,** The completion angiogram after thoracic endovascular aneurysm repair and proximal LSA coiling shows aneurysmal exclusion without endoleak; note the patent LSA bypass and antegrade distal LSA perfusion *(arrow)*. **D,** The proximal LSA has been coil embolized through brachial artery access to prevent type II endoleak.

distal fixation, and percutaneous transluminal angioplasty and celiac stenting were used in these two patients to maintain antegrade foregut perfusion. Complete occlusion of the CA was required in four patients to achieve adequate distal fixation and aneurysmal exclusion (Fig 3). The average distal neck length was 19.2 mm. An average of 3.5 thoracic stent grafts (range, 2-6) were used during each patient's initial TEVAR.

There were no perioperative deaths (≤30 days). Two intraoperative complications occurred, including an external iliac artery avulsion during device withdrawal that was repaired with open iliofemoral bypass and a common iliac artery dissection that was recognized and repaired intraoperatively with a covered stent graft. No elevations were observed in postoperative white blood cell count, serum lactate, or liver or pancreatic enzymes, and no signs or symptoms were reported of visceral, spinal, or left upper extremity ischemia.

One patient had a persistent, distal type I endoleak that required endovascular reintervention with deployment of a Zenith TX2 stent graft to eliminate the endoleak (Fig 4). One patient continued to have a small, persistent, proximal type I endoleak despite an extensive attempt at endovascular sealing; this patient has an asymptomatic, stable 6-cm aneurysm 14 months after surgery. After a mean follow-up of 30.5 months, there were no reported deaths and no reported complications of paraplegia, visceral ischemia, spinal ischemia, type II endoleak, conversion to open revascularization, left upper extremity ischemia, or aneurysm rupture.

DISCUSSION

In the 15 years since Dake et al[2] first reported the successful endovascular treatment of TAAA, numerous studies have demonstrated the safety and feasibility of this technique, with low reported morbidity, mortality, and intermediate results compared with open surgical repair.[3-5] Complete endovascular exclusion of TAAA requires adequate fixation and sealing, and anatomically inadequate proximal and distal sealing zones are the most common prohibitive factors to endovascular repair in these patients.[6]

Endovascular exclusion of the LSA origin to extend the proximal landing zone during TEVAR has been reported and is well-tolerated in selected patients.[7,8] The available data on the necessity of revascularization when stent graft coverage of the LSA is required suggest that patients with previous extensive aortic coverage, previous AAA repair, or compromised internal iliac artery circulation may benefit from LSA revascularization to reduce paraplegia risk.[9-12] Our approach in most patients requiring coverage of the LSA origin is a staged left common carotid-to-LSA bypass 3 to 5 days before TEVAR with subsequent coil embolization of the LSA stump at the time of thoracic stent graft placement.[7] When long-segment aortic coverage is required during TEVAR as in patients with extent I TAAA, we consider prophylactic LSA revascularization essential to avoid spinal cord ischemia.

Several recent case series have evaluated CA coverage during TEVAR. Vaddineni et al[13] reported seven patients who underwent planned CA coverage to achieve adequate distal sealing during endovascular repair of descending thoracic aneurysms with no deaths and no ischemic com-

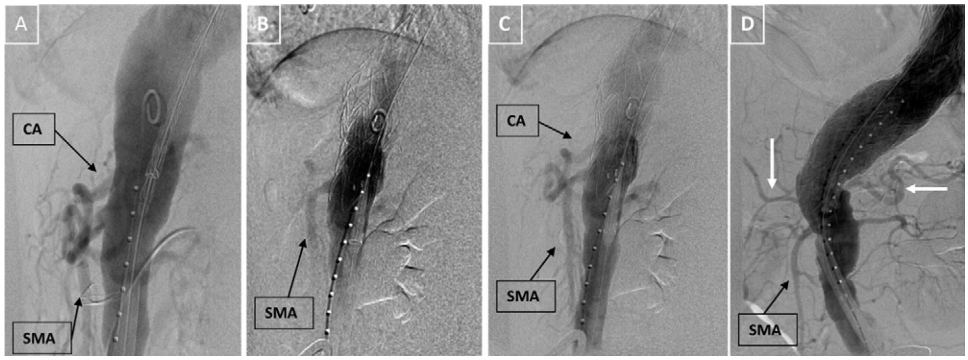

Fig 3. A, The distal extent of the thoracoabdominal aortic aneurysm is shown in this predeployment angiogram. **B,** An early-phase postdeployment lateral angiogram shows celiac artery coverage and antegrade superior mesenteric artery (*SMA*) perfusion. **C,** A late-phase postdeployment lateral angiogram shows antegrade SMA perfusion and subsequent retrograde filling of the celiac axis. **D,** Collateral filling of the hepatic and splenic arteries *(arrows)* can be seen in this anteroposterior view of the postdeployment completion angiogram.

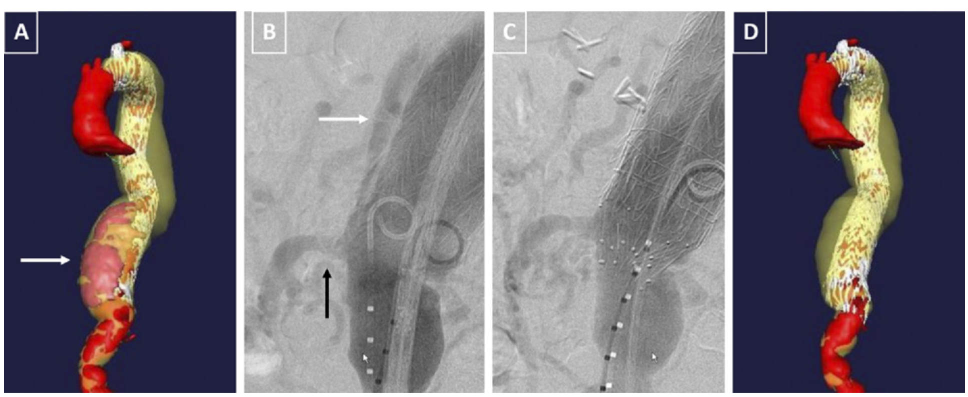

Fig 4. A, A computed tomography angiogram reconstruction using M2S software (West Lebanon, NH) shows a distal type I endoleak *(arrow)* after the initial thoracic endovascular aneurysm repair, including celiac artery coverage. **B,** Antegrade superior mesenteric artery perfusion *(black arrow)* is evident in this angiogram, which also demonstrates a distal type I endoleak *(white arrow)* in the patient from Panel A. **C,** An angiogram shows distal sealing and aneurysmal exclusion after reintervention. **D,** An M2S reconstruction of a postreintervention computed tomography angiogram note the absence of endoleak.

plications. In a review of 19 patients undergoing TEVAR with CA coverage, Leon et al[14] reported more concerning results in the 16 of 19 patients who did not undergo mesenteric revascularization: 19 complications were observed, with 3 deaths and 2 patients with postoperative paraplegia. The authors concluded that complications occurred more often without revascularization and that preoperative angiography and selective SMA angiography did not predict postoperative outcome.

The current case series reviews six patients who underwent both LSA and CA coverage to accomplish successful TEVAR of extent I TAAA. All patients underwent intraoperative completion angiography after stent graft deployment to verify SMA-to-CA collateralization and resultant liver perfusion. Although no patients exhibited signs of mesenteric ischemia postoperatively, our predetermined treatment algorithm in such cases is for immediate open surgical revascularization.

Prior reports of hybrid approaches to TAAA repair have concentrated on visceral and arch debranching before TEVAR in patients with heterogeneous aneurysmal anatomy, including extent II, III, and IV TAAA, with few reported cases of extent I TAAA management. Patel et al[15] reported a series of 23 high-risk patients undergoing hybrid TAAA repair, including 9 with extent I TAAA. Four of these nine patients had persistent postoperative endoleaks, and four had serious complications or died in the perioperative period. In the largest series of this type, Black et al[16] reported 29 patients undergoing hybrid procedures for TAAA. Three had extent I TAAA, and persistent postoperative endoleak developed in two of these three after proximal landing zone extension into the aortic arch. Using another approach, Greenberg et al[17] managed extent I TAAA with branched endografts, reporting a 7% mortality and a 10% risk of spinal cord ischemia. These results from experienced, high-volume centers indicate the highly complex and hazardous nature of extent I TAAA management in high-risk patients.

This case series details initial success using TEVAR in the management of extent I TAAA in six patients, with no deaths and no paraplegia after an average follow-up of 30.5 months. Two of the six patients required endovascular reintervention to treat postoperative type I endoleaks, and one of these two endoleaks persisted despite reintervention. The reintervention rate of 33% reinforces the challenging nature of endovascular repair of these complex aneurysms in patients deemed unfit for traditional surgical approaches.

Open repair of extent I TAAA is marked by an overall 5% to 10% risk of paraplegia and a 30-day mortality rate of 5% to 20% in the most successful series from high-volume centers.[18-20] Results from the largest recent series of hybrid approaches to TAAA indicate paraplegia rates of 0% to 9% and 30-day mortality of 0% to 21% with various techniques.[15,16] Given these results, the approach described here to manage extent I TAAA may be beneficial in patients with severe comorbidities and anatomic features that allow coverage of LSA and CA during TEVAR.

CONCLUSION

This preliminary series suggests that TEVAR can be used judiciously in the treatment of extent I TAAA as an alternative to open or hybrid repair in high-risk patients, and that landing zone extension to include coverage of the LSA and CA to achieve aneurysmal exclusion is safe in select patients. Elective LSA revascularization and subsequent coil embolization are useful adjuncts to reduce the risk of paraplegia and endoleak and to maintain left upper extremity perfusion. Mesenteric and hepatic ischemia were not seen after CA coverage.

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